HYBRID NORMALLY CLOSED DRY-FILM/ELASTOMER VALVES FOR INTEGRATED ELECTROTAXIS STUDIES

Yiling Sun[1,3], Debolina Sarkar[1,2], Ryan Adams[1], Ayelen Tayagui[1,2,3], Ashley Garrill[1,2] and Volker Nock[1,3]*

[1]*Biomolecular Interaction Centre, Electrical and Computer Engineering, University of Canterbury, NZ.*
[2]*School of Biological Sciences, University of Canterbury, NZ.*
[3]*The MacDiarmid Institute for Advanced Materials and Nanotechnology, Wellington, NZ.*

ABSTRACT

This paper presents the fabrication and characterization of novel normally closed hybrid dry-film/elastomer membrane valves for the integration of electrode arrays into lab-on-a-chip platforms for electrotaxis studies. We show valve design and fabrication processes used to integrate pneumatic microvalves with electrode arrays and fluidic handling structures. Applicability of the valves was demonstrated by compartmentalization of microspheres and motile zoospores of the oomycete *Phytophthora nicotianae.* As demonstrated by recordings of zoospore behaviour under applied electric fields, the hybrid valves provide a new platform technology to facilitate the investigation of microorganism electrotaxis in controlled environments at single-cell resolution.

KEYWORDS: Membrane valves, Hybrid dry-film/elastomer, Electrotaxis, Zoospores.

INTRODUCTION

Electrotaxis is the property of cells to sense electric fields and orient themselves as a result.[1] Microfluidic devices are ideally suited to study this behavior due to the environmental control and improved imaging capabilities they provide.[2] Their use however requires the integration of electrodes with elastomeric microfluidic channels and control structures such as normally-closed valves. The latter are difficult to realize with channels of less than 100 µm depth due to the difficulty of handling thin exclusion-molded elastomer layers. In this work, we thus describe a new type of normally closed dry-film/elastomer valve and demonstrate its use by combining it with electrode arrays to fabricate a monolithically integrated microfluidic platform for the observation of motile cells under electric fields.

EXPERIMENTAL

The platform (Fig. 1(a)) is comprised of an array of six gold electrodes on glass aligned with a fluidic chamber and two hybrid membrane microvalves, as shown in Fig. 1(b). The gas layer of the device forms the pneumatic normally closed valves at the inlet and outlet of an observation chamber. The fluidic layer with chamber structure was fabricated from dry film type photoresist (ADEX30, Microlaminates) laminated onto the substrate with pre-etched electrodes (Fig. 1(c)). The gas layer and thin membrane were fabricated separately by polydimethylsiloxane

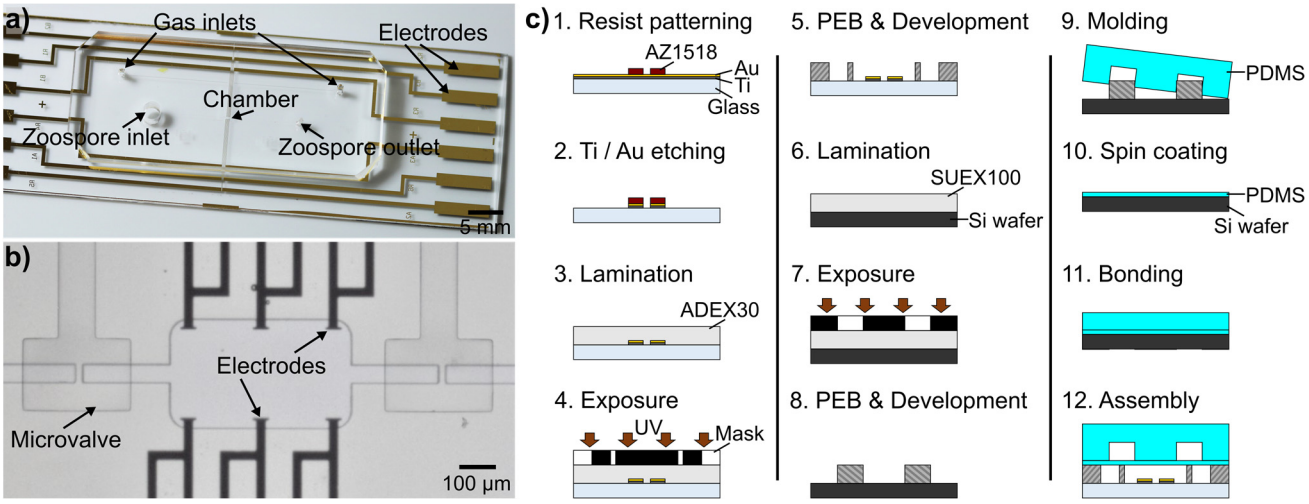

Figure 1: Microfluidic platform fabrication. (a) Photograph of assembled platform with electrodes and microvalves. (b) Light micrograph of a six-electrode array inside the observation chamber and two microvalves at the inlet and outlet. (c) Fabrication process of device, including fluidic layer (1-5), gas layer (7-9) and chip assembly to form valves (10-12).

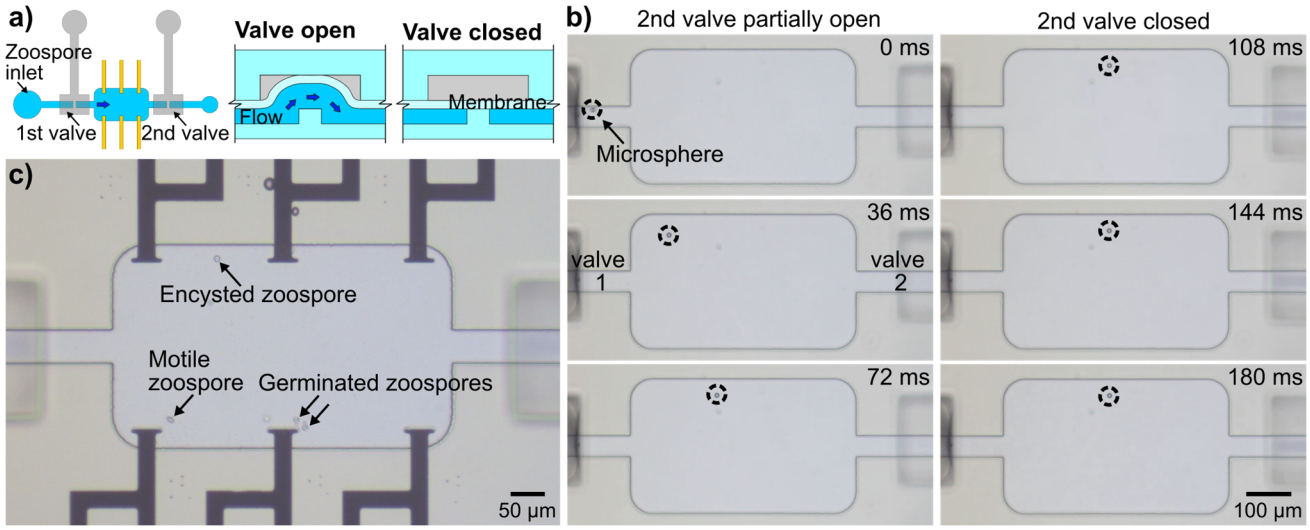

Figure 2: Compartmentalization and electrotaxis on the platform. (a) Schematic diagram of platform and microvalve operation. (b) Time sequence showing valve-driving test with the 2nd valve open (left) and closed (right) using 10 µm microspheres. (c) Light micrograph showing an example experiment with oomycete P. nicotianae *zoospores in different motility and developmental stages in response to a DC electric field of 2V applied between the top and bottom electrodes.*

(PDMS, Sylgard 184) casting from a photoresist master and spin-coating. The device was then assembled using O_2-plasma with (3-aminopropyl)-triethoxysilane treatment[3] and vacuum assisted bonding.[4] For testing, microsphere or zoospore solution was introduced from the inlet, valves were closed and, in case of zoospores, an external bias (2 V_{DC}) was applied to record the electrotactic response.

RESULTS AND DISCUSSION

As shown in Fig. 2 and video clip 1, integrated hybrid microvalves could be used to compartmentalize and stop 10 µm test microspheres once the 2nd microvalve was fully closed, demonstrating that valves were capable of controlling the retention of microspheres and motile cells in the chamber. Fully closed valves prevented any residual flow passing through the chamber. An example of a compartmentalization experiment with motile *P. nicotianae* zoospores can be seen in Fig. 2(c) and video clip 2. Zoospores remained confined to the observation chamber and different developmental stages could be observed, starting from zoospore motility in response to an electric field, subsequent encystment and germination.

CONCLUSION

We have demonstrated novel normally closed hybrid microvalves based on dry-film photoresist and elastomeric membranes. By combining these valves with gold electrode arrays, we have shown their use as platform technology for the study of the electrotactic behaviour of microorganisms, such as motile zoospores or bacteria.

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CONTACT

* Volker Nock: volker.nock@canterbury.ac.nz